RENEWAL DETAILS

| | |
|---|---|
| PUBLICATION NUMBER | EP0584871 |

PROPRIETOR(S)

Dr. Dagang Tan, Shenyang Light Industry Engineering Co.,, No.10 North Sixth Jing Street, Shenyang City, 110003, China

| | |
|---|---|
| DATE FILED | 18.08.1993 |
| DATE GRANTED | 20.11.1996 |
| DATE NEXT RENEWAL DUE | 18.08.1998 |
| DATE NOT IN FORCE | 18.08.1998 |
| DATE OF LAST RENEWAL | 01.10.1997 |
| YEAR OF LAST RENEWAL | 05 |
| STATUS | CEASED |

**** END OF REPORT ****

REGISTER ENTRY FOR EP0584871

European Application No EP93202435.9 filing date 18.08.1993

Application in German

Priority claimed:
27.08.1992 in Federal Republic of Germany - doc: 4228559

Designated States DE FR GB

Title X-RAY TUBE WITH ANODE IN TRANSMISSION MODE.

Applicant/Proprietor
DR. DAGANG TAN, Vogt-Kölln-Strasse 51, D-22527 Hamburg, Federal Republic of Germany [ADP No. 61679627001]

Inventor
DR. DAGANG TAN, Vogt-Kölln-Strasse 51, D-22527 Hamburg, Federal Republic of Germany [ADP No. 61679627001]

Classified to
H01J

Address for Service
PHILIPS ELECTRONICS, Patents and Trade Marks Department, Cross Oak Lane, REDHILL, Surrey, RH1 5HA, United Kingdom [ADP No. 00658492006]

EPO Representative
DIPL.-ING. HEINRICH HARTMANN, Philips Patentverwaltung GmbH, Wendenstrasse 35c, D-20097 Hamburg, Federal Republic of Germany [ADP No. 50603216001]

Publication No EP0584871 dated 02.03.1994 and published/granted by EPO 20.11.1996.
Publication in German

Examination requested 25.08.1994

Patent Granted with effect from 20.11.1996 (Section 25(1)) with title X-RAY TUBE WITH ANODE IN TRANSMISSION MODE. Translation filed 28.01.1997

---

26.07.1996 Notification from EPO of change of Applicant/Proprietor details
from
DR. DAGANG TAN, Vogt-Kölln-Strasse 51, D-22527 Hamburg, Federal Republic of Germany [ADP No. 61679627001]
to
DR. DAGANG TAN, Shenyang Light Industry Engineering Co.,, No.10 North Sixth Jing Street, Shenyang City, 110003, China
[ADP No. 61679627001]
Entry Type 25.14 Staff ID. RD06 Auth ID. EPT

18.10.1996 Notification from EPO of change of EPO Representative details from
DIPL.-ING. HEINRICH HARTMANN, Philips Patentverwaltung GmbH,
Wendenstrasse 35c, D-20097 Hamburg, Federal Republic of Germany
[ADP No. 50603216001]
to
DIPL.-ING. HEINRICH HARTMANN, Philips Patentverwaltung GmbH,
Röntgenstrasse 24, 22335 Hamburg, Federal Republic of Germany
[ADP No. 50603216001]
Entry Type 25.14 Staff ID. RD06 Auth ID. EPT

29.01.1997 Patent Granted with effect from 20.11.1996 (Section 25(1)) with
title X-RAY TUBE WITH ANODE IN TRANSMISSION MODE. Translation filed
28.01.1997
Entry Type 2.2 Staff ID. AB Auth ID. F54

24.07.1998 DR. DAGANG TAN, Shenyang Light Industry Engineering Co.,, No.10
North Sixth Jing Street, Shenyang City, 110003, China
[ADP No. 61679627001]
registered as address for service upon notification of withdrawal
of
PHILIPS ELECTRONICS, Patents and Trade Marks Department, Cross Oak
Lane, REDHILL, Surrey, RH1 5HA, United Kingdom
[ADP No. 00658492006]
by a letter dated 20.07.1998.
Notification of change filed on GY19.
Entry Type 7.4 Staff ID. EG1 Auth ID. RM34

17.03.1999 Patent ceased on 18.08.1998
Entry Type 12.1 Staff ID. RM86 Auth ID. RM86

**** END OF REGISTER ENTRY ****

# DECLARATION

I, the undersigned, H.A.Munsters, Sworn Translator, of Prof. Holstlaan 6, Eindhoven, The Netherlands, appointed by the Court of 'S-HERTOGENBOSCH, The Netherlands, hereby declare:

- that I am conversant with the English and German languages

- that the attached translation into the English language is a translation made by me of the published specification of European patent No.**0 584 871**

- that to the best of my knowledge and belief said English translation is a true translation of said published specification of European patent No.**0 584 871**

Eindhoven, The Netherlands, this 23rd day of January 1997

H.A.Munsters

H.A.MUNSTERS

(name and signature)

X-ray tube with anode in transmission mode.

The invention relates to an X-ray tube, comprising a transmission anode which comprises a target layer which is struck by electrons in the operating condition and consists of one or more metals of high atomic number, and also comprises a carrier layer which is connected to the target layer and consists of one or more substances of low atomic number.

X-ray tubes of this kind are known, for example from DE-A-27 29 833, from US-A-2,090,636 and US-A-3,894,239. Contradictory requirements are imposed as regards the thickness of the two layers. On the one hand, the target layer should be as thick as possible so as to convert the incident electrons into an as high as possible percentage of X-ray quanta. On the other hand, this layer should be as thin as possible so as to minimize the attenuation of the X-ray quanta generated therein. The carrier layer should on the one hand be thin enough to minimize the attenuation of the emanating X-rays and on the other hand thick enough to ensure mechanical stability and dissipation of the thermal energy produced in the target layer.

Because of these contradictory requirements, X-ray tubes of this kind are hardly used in practice, especially for a voltage range of between 50 and 500 kV which is important for medical but also industrial examinations. For these purposes use is made of X-ray tubes comprising anodes where the X-rays are emitted from the side of the anode on which the electrons are incident. Therefore, these anodes will also be referred to hereinafter as reflection anodes.

In all X-ray tubes only a small part of the applied electrical energy is converted into X-rays in the voltage range up to 500 kV; the remainder of the applied energy causes heating of the anode. Outside the X-ray tube, again only a small fraction of the X-rays generated is used as a useful radiation beam.

It is an object of the present invention to construct an X-ray tube of the kind set forth, having an operating voltage in the range of from 50 kV to 500 kV, in such a manner that the electrical energy applied for operation of the X-ray tube produces more X-radiation in the useful radiation beam than in an X-ray tube

comprising a reflection anode. This object is achieved by taking the steps disclosed in the Claim.

The invention is based on the recognition of the fact that the intensity of the X-rays is strongly dependent on the angle enclosed by the emitted X-rays relative to the direction of the electrons. Ignoring the attenuation by the target, a pronounced maximum value of the intensity occurs on the external surface of a cone whose central axis is formed by the direction of the electron beam generating the X-rays. The angle of aperture of this cone is dependent on the operating voltage and is smaller as the operating voltage is higher. For an operating voltage of 60 kV, half the angle of aperture of the cone at maximum intensity amounts to approximately 40° and amounts to approximately 10° for an operating voltage of 500 kV.

The invention utilizes this fact in that the angle between the useful radiation beam, *i.e.* the portion of the X-rays used outside the X-ray tube, and the direction of incidence of the electrons producing the X-rays is appropriately chosen.

Generally speaking, the useful radiation beam has an angle of aperture other than zero in at least one direction. In this case the angle between an X-ray at the centre of the useful radiation beam and the direction of incidence of the electrons should be chosen as disclosed in the Claim.

In the transmission-anode X-ray tubes known thus far the useful radiation beam usually extends in the prolongation of the electron path, *i.e.* the angle $\theta$ is zero.

However, there are also transmission-anode X-ray tubes in which the angle $\theta$ deviates from zero. For example, from US-A-3,894,239 there is known a rotary-anode X-ray tube with a transmission anode where an electron beam is incident approximately perpendicularly to a target layer which is inclined approximately 80° with respect to the radiation exit window. The continuous bremsstrahlungs spectrum produced in the target layer should thus be attenuated to a substantially higher degree than the fluorescent radiation produced in the target layer.

Furthermore, from Fig. 7 of DE-A- 27 29 833 there is known an X-ray tube, comprising an annular anode, where the X-rays are generated by means of two groups of cathodes which are distributed along the circumference of the anode, said cathodes being situated to both sides of a central plane extending through the source. As a result, each time an angle $\theta$ of 45° is obtained.

None of the cited publications utilizes the fact that the X-rays are

particularly intense in an angular range between 15° (at high tube voltages) and 40°(at low tube voltages).

Finally, from WO-A-92/03837 there is known an X-ray tube, comprising a reflection anode, where the electrons are incident on the anode at an angle of 10° (instead of the customary 70°-90°) and where the useful radiation beam extends at an angle of from 5° to 15° relative to the anode. However, the radiation exit window is then liable to be strongly heated by scattered electrons.

In an embodiment of the invention, the weight w of the target layer per unit of surface area, being essential for the X-ray yield, expressed in g/cm², at least approximately satisfies:

$$w = 1.08 \cdot 10^{-6} \cdot (A/Z)^{2.5} \cdot U^{1.6} \cdot \cos\beta,$$

where A is the relative atomic weight and Z is the atomic number of the metal of the target layer, U is the rated operating voltage of the X-ray tube in kV, and $\beta$ is the angle enclosed by the direction of incidence of the electrons relative to the normal to the target layer. For an X-ray tube comprising a tungsten target layer, this results in a weight per unit of surface area of 0.017 g/cm² or a thickness of 8.6 $\mu$m (for $\beta=0°$), in the event of an operating voltage U = 100 kV.

The invention can be used for different X-ray tubes for different applications. In a preferred embodiment of the invention, the tube is constructed as a rotary-anode X-ray tube, the target layer (for example, of tungsten and/or rhenium) being provided on the surface of a truncated cone which encloses an angle relative to the direction of the X-rays used outside the X-ray tube, which is smaller than the angle existing between said direction and the direction of the incident electrons. The anode is then shaped as a dish which is symmetrical relative to its axis of rotation, whose inner surface, on which the target layer is provided, faces the electron source emitting the electrons, and whose useful radiation beam emerges from the external surface preferably at an angle of 90° relative to the axis of rotation.

The invention will be described in detail hereinafter with reference to the drawings. Therein:

Fig. 1 shows the principle of a part of a transmission anode, and

Fig. 2 shows a rotary-anode X-ray tube comprising a transmission anode in accordance with the invention.

The transmission anode shown in Fig. 1 comprises a target layer 1 of a

metal having a high atomic number which is provided on a carrier layer 2 of a substance having a low atomic number. The target layer 1 may consist of, for example tungsten or rhenium or of an alloy of these metals; other suitable metals for the target layer 1 are platinum or thorium. The carrier layer 2 may consist of graphite or beryllium and may have a thickness such that on the one hand adequate mechanical stability is obtained and on the other hand the attenuation of the X-radiation is as low as possible.

The arrow 3 denotes an electron beam which is incident on the target layer 1 at an angle $\beta$ relative to the normal. X-rays are is thus produced which propagate as a cone around the point of incidence. Theoretical and experimental investigations, however, have demonstrated that, ignoring the attenuation by the target, the X-rays propagating on the surface of a cone (whose apex is situated at the point of incidence of the electrons and whose symmetry axis extends parallel to the electron beam direction) with a given angle of aperture $\theta$ have the highest intensity. The upper boundary ray 4a and the lower boundary ray 4b of this cone are shown in Fig. 1. The half angle of aperture $\theta$ of this cone depends on the operating voltage, approximately in conformity with the following Table:

| $U/kV$ | 60-100 | 100-150 | 150-200 | 200-350 | 350-500 |
|---|---|---|---|---|---|
| θ | 40°-35° | 35°-30° | 30°-25° | 25°-20° | 20°-15° |

Therefore, the X-ray tube must be constructed so that the direction of the useful radiation beam is coincident with the direction of one of the rays on the conical surface. The X-rays produced in the target layer can then extend at different angles relative to the layer planes, the drawing showing the smallest angle $\alpha_1$ and the largest angle $\alpha_2$. The following equations hold for these angles:

$$\alpha_1 = 90°\text{-}\beta\text{-}\Theta \tag{1}$$

$$\alpha_2 = 90°\text{-}\beta+\Theta \tag{2}$$

The target layer mass per unit of surface area which is optimum for the radiation yield is given approximately by the relation:

$$w = 1.08 \cdot 10^{-6} \cdot (A/Z)^{2.5} \cdot U^{1.6} \cdot \cos\beta \tag{3}$$

Therein, A is the relative atomic weight and Z is the atomic number of the metal of the target layer. $\beta$ is the angle of incidence of the electrons, *i.e.* the angle enclosed by the direction of the electron beam 3 relative to the normal to the target layer. When the

target layer consists of an alloy of two or more metals, the mass of the target layer per unit of surface area is calculated by calculating the value w in conformity with the equation (3) for each metal of the alloy, the calculated values being summed weighted in proportion to their pressure in the alloy.

When the radiation exit direction has been selected in conformity with the Table and the thickness of the target layer has been proportioned in conformity with the equation (3), the intensity of the X-rays in the useful radiation beam will be significantly higher, for the same tube voltage and the same tube current, than in an X-ray tube comprising a reflection anode where the angle between the direction of electron incidence and the radiation exit direction amounts to approximately 90°. The increase of the intensity will be greater as the tube voltage is higher. However, when the X-ray tube operates at a voltage other than its rated voltage, these intensity advantages decline.

Fig. 2 shows an embodiment of a rotary-anode X-ray tube comprising a transmission anode in accordance with the invention. The X-ray tube comprises a tube envelope 5 which consists of glass and in which there are arranged a cathode arrangement 6 and an anode arrangement 7. The anode arrangement comprises a transmission anode 2 which is connected to a rotor 8 in known manner and is rotably journalled inside the X-ray tube. The rotor is driven by means of a stator which is arranged outside the glass envelope and which is not shown in Fig. 2.

The transmission anode comprises a carrier member 2 which consists of graphite and is shaped as a dish or plate which opens towards the cathode arrangement 6. At the area of the transmission anode on which the electron beam 3 from an electron emitter mounted on the cathode arrangement 6 impinges, there is provided a target layer 1, consisting of rhenium, which target layer is deposited on the carrier member 2. If the X-ray tube is intended for computer tomography purposes, and hence is constructed for an operating voltage of 150 kV, and if the electron beam 3 is incident on the layer at an angle of 40° relative to the normal direction, the mass of this layer amounts to 0.024 g/cm$^2$, relative to the unit of surface area, in conformity with the equation (3). This is achieved by means of a rhenium layer having a thickness of 11.5 $\mu$m.

The X-ray tube is arranged inside a housing, merely a part of the housing wall 10 thereof being shown at the right-hand side in Fig. 2. The wall of the housing comprises a lining of an X-ray absorbing material, for example lead, of sufficient

thickness. A radiation exit window 11 of an X-ray transparent material, for example aluminium, is provided only at the level of the target layer, so that useful radiation can emerge only at that area. The useful radiation then propagates perpendicularly to the axis of rotation and at an angle of 30° relative to the direction of the electron beam. In the case of CT examinations, a substantially flat, fan-shaped radiation beam is formed by the radiation exit window in the direction perpendicular to the plane of drawing in Fig. 2. The direction of the largest dimension of the X-ray exit window then also extends perpendicularly to the plane of drawing.

Even though the invention has been described on the basis of a rotary-anode X-ray tube comprising a glass envelope and intended for medical examinations, the invention can also be used in other embodiments. For example, instead of a rotary anode use can be made of a stationary anode. Instead of an X-ray tube comprising a glass envelope, use can be made of an X-ray tube comprising a metal envelope in which the cathode and/or the anode are connected to the metal envelope *via* insulators. The X-ray tube can also be used for non-destructive testing in the industrial field; a particularly high efficiency is obtained for the range of tube voltages (200 - 500 kV) used for these purposes.

Claims:

1. An X-ray tube, comprising a transmission anode which comprises a target layer which is struck by electrons in the operating condition and consists of one or more metals of high atomic number, and also comprises a carrier layer which is connected to the target layer and consists of one or more substances of low atomic number, characterized in that the angle $\theta$ between the direction of incidence of the electrons and the direction of the central ray of the useful x-ray beam emitted through the carrier layer is between 10° and 40°.

2. An X-ray tube as claimed in Claim 1, characterized in that the angle $\theta$ and the rated operating voltage U of the X-ray tube satisfy at least approximately the following relation:

| $U/kV$ | 60-100 | 100-150 | 150-200 | 200-350 | 350-500 |
|---|---|---|---|---|---|
| $\theta$ | 40°-35° | 35°-30° | 30°-25° | 25°-20° | 20°-15° |

3. An X-ray tube as claimed in any one of the preceding Claims, characterized in that the weight w of the target layer per unit of surface area, expressed in g/cm$^2$, at least approximately satisfies the relation:

$$w = 1.08 \cdot 10^{-6} \cdot (A/Z)^{2.5} \cdot U^{1.6} \cdot \cos\beta$$

where A is the relative atomic weight and Z is the atomic number of the metal of the target layer, U is the rated operating voltage of the X-ray tube in kV, and $\beta$ is the angle enclosed by the direction of incidence of the electrons relative to the normal to the target layer.

4. An X-ray tube as claimed in any one of the preceding Claims, characterized in that it is constructed as a rotary-anode X-ray tube, and that the target layer (1) is situated on the surface of a truncated cone which encloses an angle ($\alpha_1$) relative to the direction of the X-rays used outside the X-ray tube, which angle is smaller than the angle $\theta$ existing between said direction and the direction of the incident electrons.

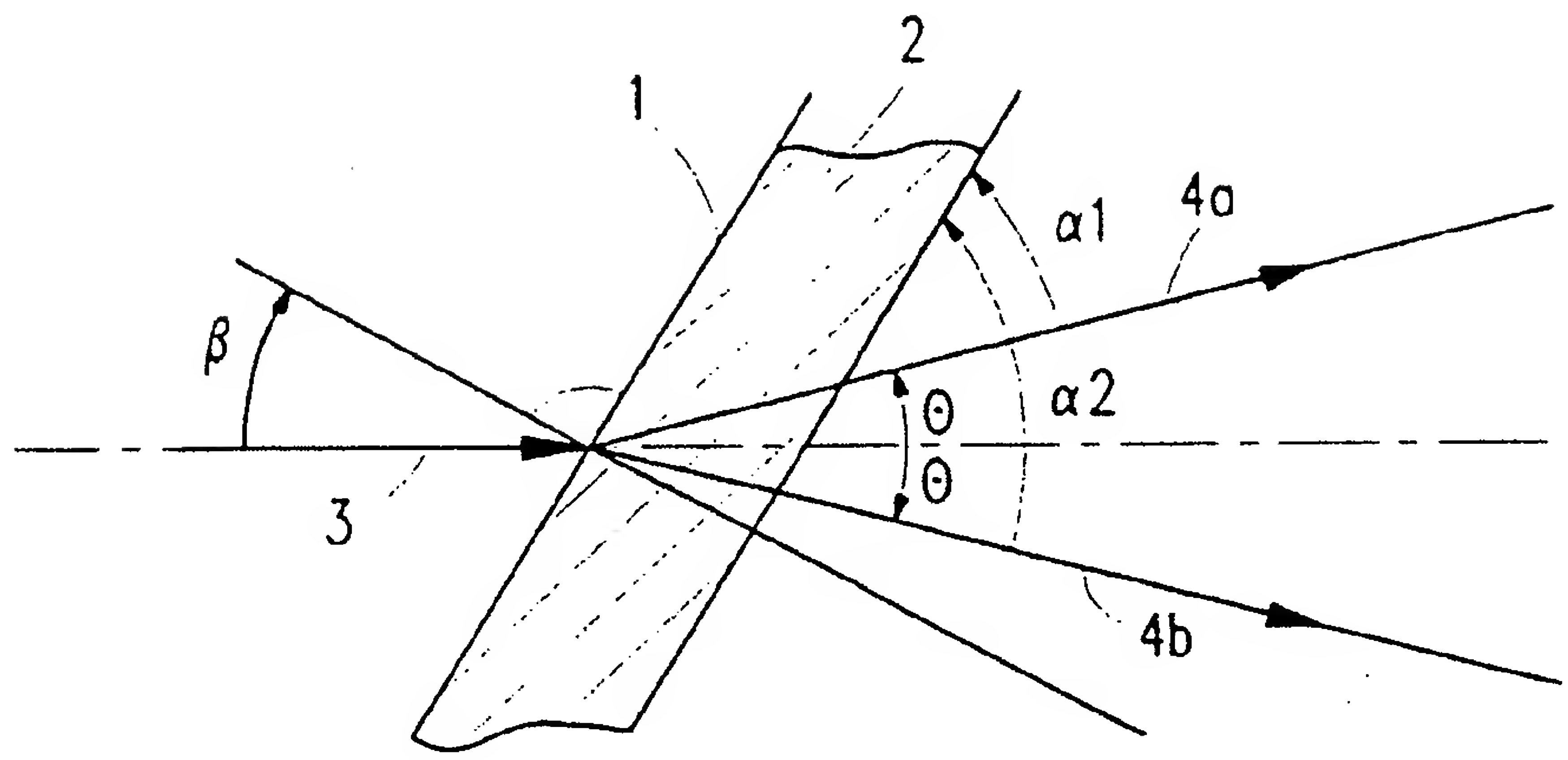


Fig.1

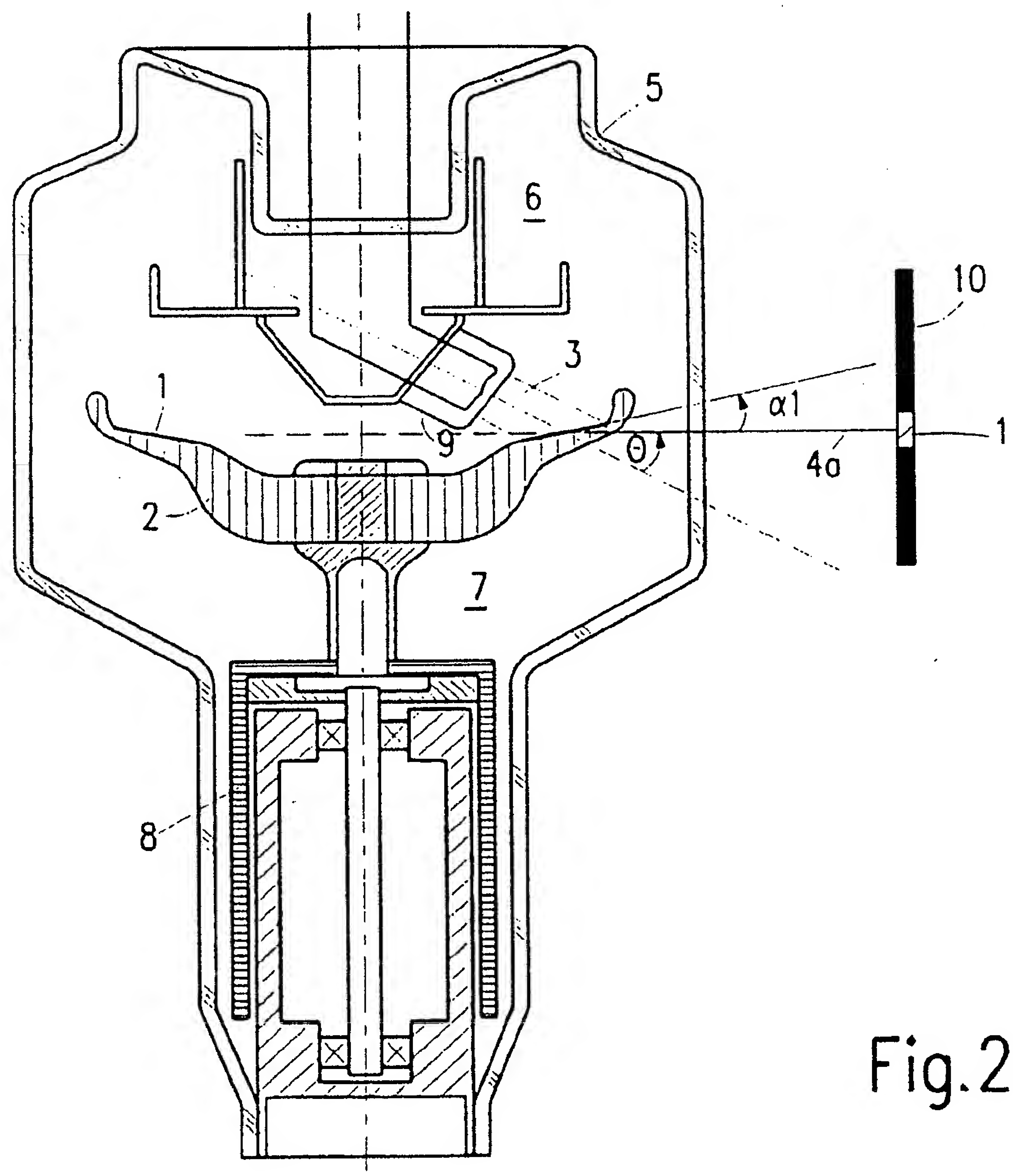


Fig.2